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L. O. HOWARD, Chief

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## THE GRASSHOPPER OUTBREAK IN NEW MEXICO DURING THE SUMMER OF 1913.[1]

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### INTRODUCTION.

Of the several important grasshopper outbreaks in the United States during the summer of 1913 that of the so-called long-winged

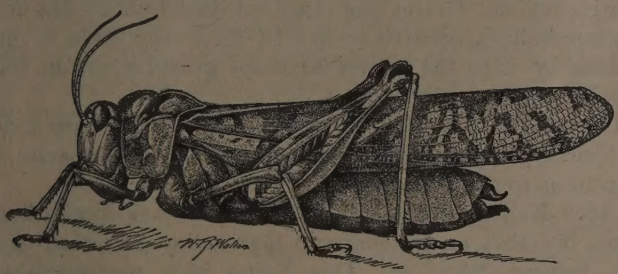

FIG. 1.—Long-winged grasshopper (*Dissosteira longipennis*): Adult female. About one-third enlarged. (Original.)

grasshopper (fig. 1) in the Pecos Valley of New Mexico proved one of the most interesting. Though more or less important outbreaks of this grasshopper have been reported heretofore, very little actual data pertaining to this species appears to have been assembled.

The writer, under the direction of F. M. Webster, in charge of cereal and forage insect investigations of the Bureau of Entomology, spent the month of June, 1913, in the field investigating this rather unusual invasion.

The data are of necessity in certain phases somewhat incomplete since the investigations were carried on entirely under field conditions, although a very considerable amount of information relative to this species was obtained and is herein presented.

[1] The grasshopper discussed in this paper is scientifically known as *Dissosteira longipennis* Thomas; synonym, *Oedipoda nebracensis* Bruner.

## HISTORY IN AMERICA.

This long-winged grasshopper was originally described by Cyrus Thomas in 1872 under the name of *Oedipoda longipennis*, from a male specimen, marked "Kansas," submitted to him in a collection from the Agricultural Department. C. V. Riley claims to have collected this species in Colorado on his first trip to that State in 1867.

In 1876 S. H. Scudder proposed a new genus (Dissosteira) for the reception of *Oedipoda longipennis* Thom. and *Gryllus carolina* Linn., designating the latter species as the genotype.

In 1875 Philip R. Uhler found this species in small numbers in the region west of Colorado Springs, Colo.

In 1891 Lawrence Bruner, while upon a general tour of observation to investigate rumored grasshopper ravages in different parts of the Western States, stated that the species causing the alarm in Colorado was "* * * a rather rare species, known as *D. longipennis*, it occurring at that time over 400 sq. miles of territory in sufficient numbers to materially injure the grasses growing on the range of the entire region. Grains and other cultivated plants did not appear to be especially attractive to it. In fact, very little or no injury was done by it to the cultivated crops growing within the region infested."

Between July 10 and 19, 1891, the late E. H. Popenoe visited Lincoln County, Colo., where grasshoppers of this species were so numerous as to stop the trains.

In 1892 Kellogg stated that this species was locally hurtful in Kansas, but that no serious crop destruction was threatened. He stated further, "* * * This locust is a nonmigratory form, occasionally abundant on the plains of eastern Colorado. It sometimes occurs in sufficient numbers in restricted areas to destroy all vegetation."

In 1895 Bruner noted this species "* * * Out on the plains away from the foothills and irrigating ditches," as quite abundant over a large portion of Colorado and Nebraska. He believed "* * * stony hillsides furnished a suitable place for the increase of *D. longipennis* and several other barren-ground species."

In 1896 Bruner again noted this species abundant in Colorado and Nebraska, recording it attacking and actually destroying entire fields of small grains, some corn, potatoes, and a number of garden plants.

In 1898 this species was occasionally noted in western Kansas by S. J. Hunter, who stated that in Edwards County this locust was abundant in a portion of an alfalfa field of 320 acres. This was first observed July 6. On September 1 females of this species were seen ovipositing in this field. It was his opinion that this colony

was bred and reared upon this ground. In the same year he also recorded: "On the evening of July 21 the locusts came from the west down into Colorado Springs in countless numbers."

In 1900 this insect invaded the town of Las Vegas, N. Mex., in great numbers and crushed specimens were everywhere seen on the sidewalks.

In 1904 Bruner wrote, regarding this species, "A native of the high prairies of western Kansas, Nebraska, eastern Colorado, and Wyoming; not nearly so abundant as it was five years ago."

The 1913 outbreak of this species extended over 400 to 500 square miles, the prairie grasses, grain, and garden crops within this area being in great part devastated. Herds of cattle usually grazing within this infested area were forced to travel from 11 to 13 miles for grazing facilities, and would return to their usual watering places only at intervals, varying from 24 to 56 hours. Freight and passenger trains were repeatedly stopped by grasshoppers massing upon the railroad tracks, this being frequent from the middle of May until the first of July.

The prairie grasses within the infested area were so completely ravaged that hardly a surface depression of the soil could be located which was not from one-fourth to completely filled with grasshoppers' droppings.

## DISTRIBUTION.

This species is native to the western United States. Since Thomas described the species from western Kansas it has been found in Colorado, Wyoming, Nebraska, Idaho, New Mexico, Texas, and Oklahoma.

## SEASONAL HISTORY.

The eggs of this species in New Mexico evidently commence to hatch en masse during the first week of May, though a few nymphs may probably appear during the latter part of April.

Adults were first noted on June 4, and by June 24 the majority of the grasshoppers were in the adult stage. However, third and fourth stage nymphs were present in numbers up to the second week in July.

So far as known, this species has but a single generation per year, the eggs being deposited during late August and early September.

## A MIGRATORY OR NONMIGRATORY SPECIES?

In 1892 Kellogg stated that in Kansas this grasshopper is a nonmigratory species.

In 1913, from May 4 to June 24, nymphal droves of this species traveled in a northeasterly direction some 15 to 18 miles, ravaging the entire growth of prairie grasses in their path.

The species is gregarious, the early maturing adults remaining with the nymphal droves until the majority have attained the fully-winged state.

The adults are readily attracted to lights, having been taken at Clovis, N. Mex., during June, 1913, about 25 miles north of Elida, where the main nymphal droves were located at the time.

In the winged state these insects are very wary and are exceptionally strong fliers.

## ORIGIN OF OUTBREAK.

This outbreak originated from a tremendous swarm of adults flying from some unknown point to the north. These settled in the outlying districts of Elida, N. Mex., during the latter part of August and early September. During one evening, when swarms of this species were passing over Elida, large numbers of them flew against the plate-glass window of a brilliantly lighted barber shop. The following morning several bushels of dead grasshoppers were heaped on the sidewalk.

## BREEDING GROUNDS.

The breeding grounds on which these swarms settled to deposit their eggs were in most part in a chain of sandhills running from about 8 to 10 miles northwest to southwest of Elida. Another considerable swarm settled and deposited eggs in the sandhills 6½ miles southeast of Elida.

On May 4, 1913, at a point 8 miles northwest of Elida, Mr. B. W. Kinsolving noted the tiny grasshoppers coming out of the sand "by the million." Watching this area for a little over a week Mr. Kinsolving says: "Tiny hoppers appeared to be coming out of the sand continually. One evening during a heavy shower certain areas of this breeding ground were covered at least 6 inches deep with tiny hoppers."

On May 6, 1913, 6½ miles southeast of Elida, Mr. Bruce Marsh noted the tiny grasshoppers issuing from the sand in an area nearly 1 mile square, "the ground over this area appearing like a living mass of crawling maggots."

At about the same time the cowboys on the Littlefield ranch, 8½ miles southwest of Elida, noted the sand moving up and down over a great area. When examined they found "countless millions of tiny hoppers crawling to the surface."

Though the major portion of the egg pods were deposited in the sandhills during the fall of 1912, the writer was informed by several parties that some of the eggs, at least, were deposited in hard land. This is very probably true, but at best they constituted a very small percentage.

## METHODS OF TRAVEL.

Grasshoppers of this species appear to have a decided preference for massing together and traveling over barren areas, such as roadways, footpaths, and along railroad tracks and right of ways. Over such areas, under favorable weather conditions, immense droves 1 or 2 miles in length, massed closely together, travel along at a rapid gait, all generally traveling in the same direction. Though large droves mass and travel over the prairie proper, the rate of travel is somewhat less than that of the droves passing over barren areas.

Grasshoppers in the third nymphal stage travel at the rate of from 8 to 12 feet per minute; those in the fourth instar from 15 to 20 feet per minute. The rate of travel of nymphs in the first two instars is proportionally less. Nymphal droves of these grasshoppers, under proper weather conditions, travel from 1 to 2 miles a day.

Adults taking flight during a heavy wind fly with the wind, though generally facing it during the rise from the ground to the desired altitude, which usually is from 30 to 40 feet. Adults have been noted to alight on the surface of water and then easily take wing therefrom.

## WEATHER CONDITIONS.

Weather conditions are a very important factor in the dispersion of the grasshoppers, at least during that period when the majority are in the nymphal stages.

Throughout the month of June, 1913, the amount of precipitation in New Mexico was greatly in excess of normal.

On dark, cloudy days or during rainy weather the grasshoppers travel very little. Under such conditions they generally collect beneath available shelter, or mass upon the prairie to feed, or slowly wander around with no apparent object in view. If, however, during one of these periods the sun breaks through the clouds to shine brilliantly for a few moments, every individual becomes active and almost immediately the entire drove is rapidly moving along its usual course of travel. The moment the sun disappears travel ceases as promptly as it began, and the former state of inactivity is soon restored.

During fair, bright sunny weather travel usually commences early in the forenoon and continues until the latter part of the afternoon.

Under high prevailing wind conditions the grasshoppers will seek the windward side of any available shelter, there to remain until the wind has ceased or considerably abated.

## FEEDING HABITS.

The major portion of the feeding takes place during the early morning hours and the last part of the afternoon, although intermittent feeding is indulged in throughout the day. Under favorable weather conditions the approximate hours of feeding are from daylight until 8 or 9 o'clock in the forenoon, and from 3 to 4 o'clock until sundown during the afternoon. Apparently little or no feeding takes place during the night. The foliage may be entirely devoured or irregular patches cut out from the margin of the leaves. The stems or stalks may be partly or entirely girdled and cut off.

## FOOD PLANTS.

Grama grass (*Bouteloua oligostachya*), buffalo grass (*Bulbilis dactyloides*), and mesquite grass (*Bouteloua hirsuta*) are by preference the most relished food plants of this species. Fields of maize, kafir corn, and millet were completely devastated. Millet is in all instances a most desirable food plant. Mr. Hobson, of Elida, informed the writer that he noted the grasshoppers massing in 5 acres of millet on his farm, and in less than 30 minutes every plant had been eaten to the ground. Sorghum is fed upon to a slight extent, but is seldom disturbed if other more desirable food plants are readily available.

Truck crops in the infested area were entirely defoliated, including the following plants: Cultivated mustard, radish, lettuce, squash, sweet potato, young white potato (old plants seldom disturbed), tomato, sweet corn, and immature onion plants.

Under certain conditions Russian thistle (*Salsola tragus*) is readily fed upon, and slight feeding upon soapweed (*Chlorogalum pomeridianum*) has been noted.

Though S. J. Hunter has recorded this species as being abundant in part of a 320-acre tract of alfalfa in western Kansas during 1898, nymphs of this species forwarded to the Wellington, Kans., laboratory, and confined in a Comstock cage placed over alfalfa plants, failed to display any desire for feeding upon this plant, the nymphs ultimately dying from apparent starvation.

## PREDACIOUS ENEMIES.

Among the more important bird enemies noted to be feeding upon grasshoppers during this invasion were the desert horned lark (*Otocoris alpestris leucolaema*), western meadowlark (*Sturnella neglecta*),

desert sparrow hawk (*Falco sparverius phalaena*), nighthawk (*Chordeiles virginianus*), killdeer (*Oxyechus vociferus*), and quail (*Colinus virginianus*). The results of further investigations in cooperation with the Biological Survey on the destruction of grasshoppers by birds in New Mexico will be published in another connection.

Several species of lizards, which were very numerous in this locality, fed voraciously upon the nymphs. Oftentimes lizards were noted so bloated from grasshopper feeding that travel was accomplished only with great difficulty. Horned toads were also heavy feeders upon the immature grasshoppers.

While the large droves were passing through the prairie-dog towns these animals appeared to feed upon the grasshoppers in numbers.

## PARASITIC ENEMIES.

A dipteron, *Sarcophaga kellyi* Ald., was found to be by far the most important factor in the control of this species, and it was equally efficient as a parasite upon both the nymphs and adults.

Larviposition by the female of *S. kellyi* was continually noted throughout the month of June. The female, as far as observed by the writer, always chose individuals freshly molted or inactive, but in an apparently healthy condition.

During the latter part of June the grasshoppers were enormously reduced in numbers from parasitism by *S. kellyi*. It was a simple matter to count 15 or more dead grasshoppers to the square foot over large areas. The grasshoppers died in such numbers in some localities that ranchers informed the writer that certain droves were almost completely destroyed.

On June 16 a female of *S. kellyi* was noted to deposit tiny maggots on the dorsum of the thorax (pronotum) of a freshly molted nymph. This nymph was captured as the fly finished the act. The fly in question was then noted to rest upon the thorax of a second nymph, where it commenced to larviposit. At this time, while in the act of depositing a maggot, she was captured, and, although badly crushed, the specimen was not so greatly disfigured but that comparison with previously reared specimens proved beyond a question that all were identical. Careful comparison of this female taken in the act of larviposition, with another female noted to be larvipositing in the same manner, but not captured while in the act, proved again that both were the same species.

From the captured nymph above noted six specimens of *S. kellyi* were reared.

This was the only female which the writer was able to capture in the act of depositing the tiny maggots, but it abundantly determined the method of larviposition utilized by *S. kellyi* in parasitizing *D.*

*longipennis.* Sarcophagids were continually noted to larviposit on nymphs left comatose upon the open prairie, after having been stung by a wasp (*Priononyx atrata* Lep.). In not a single instance was it possible to note a sarcophagid endeavoring to strike a moving nymph or flying adult.

When large numbers of the grasshoppers were molting at approximately the same time the familiar noise of hundreds of female sarcophagids in search of their victim was easily heard. Hot, sunny weather greatly stimulated the activities of the flies, as well as those of the grasshoppers, whereas cold, cloudy, or rainy weather invariably checked them.

The female, upon locating a suitable victim, was observed to alight upon the dorsum of the thorax and quickly deposit several living maggots, which, encountering only the soft, tender membrane, speedily made their way into the body cavity of their host. The maggots are capable, however, of entering a host which is fully dried out and hardened, the writer having noted a female sarcophagid to larviposit on a grasshopper nymph (fig. 2) which had been stung by *Priononyx atrata* and left upon the open prairie beside the partially excavated hole of the wasp; the maggots deposited soon entering the host and the puparia later emerging, to give issuance to adults of *S. kellyi.*

FIG. 2.—Long-winged grasshopper: Nymph which had been stung by the wasp *Priononyx atrata* and on which the parasitic fly *Sarcophaga kellyi* afterwards deposited a larva. About one-third enlarged. (Original.)

The number of living maggots deposited by the female upon an individual host during one period of larviposition would vary from 1 to 7 or more, although from 3 to 6 appeared to be the more general. The writer has reared individuals from five puparia of *S. kellyi* taken from an adult of *Dissosteira carolina* captured at Wellington, Kans., on the wing July 9, 1913, the maggots emerging from the host July 10. As many as 16 maggots have been found in the body cavity of a large nympth of *Hippiscus* sp. in New Mexico.

The maggots of *S. kellyi* usually issue from their host just posterior to the anterior coxa. A certain percentage, however, depart from the host by boring through the abdomen at the segmental sutures or by passing through the anal orifice. Upon leaving the host the maggots may enter the soil directly beneath their victim, or they may crawl several feet away before entering the ground. The summer generations of *S. kellyi* pupate from one-half to 2 inches

below the soil surface, but very probably the maggots or puparia of the hibernating fall generation enter the soil to a much greater depth.

*Sarcophaga kellyi* is a plural-brooded species, several generations occurring during the season. At least two and probably three generations went through to maturity as parasites of *D. longipennis* from early May to the middle of July.

The grasshoppers will die from the effects of the parasitism while in the act of feeding, and thus they are found hanging to a grass stem, the mandibles firmly attached, in their last dying grasp. The dead grasshoppers lying on the ground may be full of crawling maggots still feeding or endeavoring to issue from their host to enter the soil. When the maggots have emerged from the host only the shell of the grasshopper remains.

Methods of larviposition much similar to those noted by the writer have been recorded by Kunkel d'Herculais on *Sarcophaga clathrata* Meig. in Algiers during 1893–1905. Apparently the foregoing writer had only one species of Sarcophaga involved, as was true in the case of the writer during the present studies.

Second in importance as a controlling factor of *D. longipennis* was the preying upon the nymphs by the sphecid wasps *Prionony x atrata* Lep.

These wasps were always present in large numbers among the hoppers. Being very diligent workers, apparently working from sunrise to sunset during favorable weather conditions, the numbers of the grasshoppers were greatly depleted from their efforts. During the observations of the writer, however, only nymphs were noted to be attacked.

In nearly every instance the single nymph placed in each nest is stung before the excavation is undertaken, but occasionally the burrow will be completed before this is done. However, the female wasps frequently sting several nymphs during the period of constructing a single nest, and in one instance, observed by the writer, as many as five were stung by a single female while excavating an individual burrow. In this case it was the last nymph stung which was drawn into the burrow. The nest finished, the Prionony x flew away, leaving the other four victims lying upon the prairie in a comatose condition. The nymphs once stung by Prionony x seldom, if ever, regain consciousness. This habit, naturally, increases the efficiency of this species.

Usually the hopper is stung in the abdomen, but stinging in the venter of the head regions is common. The wasp, approaching the victim unawares, generally seizes and stings it so quickly that the grasshopper has little opportunity to offer any effective resistance. When a nymph is aware of the presence of a Prionony x it will suddenly assume the very characteristic protective attitude of defense.

Crouching close to the ground, it will raise the posterior pair of legs above the abdomen in the shape of an inverted V, whereupon it will remain perfectly quiet until the wasp has apparently departed. Though the Prononyx will occasionally attack a nymph while in this protective attitude, a severe struggle generally ensues, with the grasshopper infrequently the victor.

A large number of the nymphs which have been stung by Prononyx and left upon the prairie while she is building the nest are in the meantime larviposited upon by *Sarcophaga kellyi*.

The nest is usually built in compact sand. Between railroad tracks and along the right of ways are also desirable nesting places. The excavation of the burrow is commenced by the female rapidly scratching away the surface with the anterior pair of legs. As the depth of the burrow increases the head is cooperatively brought into play with the workings of the anterior legs, when finally the excavation of the burrow is completed by the wasp bringing huge mouthfuls of the soil to the surface. The burrow is excavated almost vertically downward to a depth of 1½ to 2 inches and about one-half inch in diameter. The bottom of the burrow is then excavated in a horizontal direction until a cavity is made sufficiently large conveniently to permit of a nymph being placed within it. In dragging the nymph to the burrow the wasp assumes a horizontal position astraddle the victim. Seizing the nymph with her mandibles at the base of the antennæ, she drags it venter down to the entrance of the burrow. Then facing the nymph, still holding it at the base of the antennæ, she backs into the burrow, dragging in the nymph head foremost behind her. Placing the nymph in the horizontal cavity at the base of the burrow, venter down, in a horizontal position, she deposits a single egg. This egg, white in color, elongate oval, and somewhat curved, is invariably attached to the tender membrane at the base of the posterior coxa.

The egg having been deposited, the wasp proceeds to the surface. Taking a position, back to the burrow, she rapidly scratches the excavated soil into the hole. From time to time she packs down the soil with her head, which she uses as a most efficient ramming instrument. The excavation filled, the wasp carries small sticks, stones, cinders, and the like—these often much heavier than the wasp herself—and places them over the burrow. The time elapsing from the moment the nest is started until its completion usually varies from 30 minutes to 1 hour.

Though it is virtually impossible for the human eye to locate a completed Prononyx nest, there is a bembecid wasp, *Megastizus unicinctus* Say, a secondary upon *Prononyx atrata*, which without the least difficulty locates the Prononyx nest with the greatest exacti-

tude. After Prionony x has completed a nest, a Megastizus will locate it, reexcavate the burrow, and proceed to destroy the egg deposited upon the nymph by the sphecid. This egg is apparently destroyed by the Megastizus crushing it between her mandibles. The Megastizus then deposits upon the nymph an egg of her own.

Megastizus is not particular about refilling the burrow, nor does she attempt to hide the location of it in any manner, as does the Prionony x. Oftentimes Megastizus will leave the nest when the burrow is not more than half refilled with soil. Occasionally the Prionony x will be driven from her nest by Megastizus while in the act of filling up her burrow. Neither Prionony x nor her nest, however, were ever noted to be disturbed by Megastizus until after the prey had been placed in the burrow.

Megastizus never attempted to sting a grasshopper during the present observations, but preyed upon Prionony x entirely, in the rôle of a secondary within the sphecid's nest. Being present in considerable numbers, it most certainly affected the efficiency of Prionony x to a great extent.

## ARTIFICIAL REMEDIES.

The most effective artificial means of exterminating the grasshoppers of this species was found in the use of the poisoned bran mash. This was made as follows: Thoroughly mix together in the dry state 25 pounds of wheat bran and 1 pound of Paris green. Into a separate receptacle containing 2 quarts of a cheap molasses or sirup add the juices and finely ground skin and pulp of three oranges or lemons. Dilute the molasses mixture in 2 gallons of water and add to the poisoned bran mixture. Thoroughly mix the two together, adding enough more water, if necessary, to bring all to a stiff dough. This amount of poisoned bait will treat from 5 to 10 acres.

The bait should be sown broadcast early in the morning, before sunrise, in strips 1 rod apart, over the area to be treated. The most satisfactory method of distributing the bait is to sow it from the rear end of a buggy.

In using the poisoned bait as above, with lemons as the fruit employed, tremendous numbers of the grasshoppers were exterminated. As many as 75 dead grasshoppers per square foot were frequently found, several days after the application, over large areas. The grasshoppers usually die from 6 to 80 hours after taking the poisoned bait into the system.

Coarse-flaked brans should be used in preference to the fine-flaked varieties. Only those brands of Paris green which are guaranteed to contain not less than 55 per cent of arsenic should be employed. Arsenate of lead should not be used in any form. There have ex-

isted some differences of opinion as to whether oranges or lemons make the bait more effective. As 75 per cent of the efficiency of the bait is attributed to the use of these citrous fruits, this point is naturally a very important one. The writer, in extensive experiments with different species of grasshoppers, has yet to note any material advantage or marked difference of efficiency in favor of either oranges or lemons.

The Criddle mixture, as commonly employed in grasshopper extermination, was not experimented with during the present investigation for lack of available material. But as nymphs of this species are voracious feeders on horse droppings and dried "cow chips" there seems little question but what this bait could be effectively used if the ingredients were readily available.

On account of the irregularity of the land in the infested area of this outbreak the use of a hopperdozer was not practicable.

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